28: Grigoriev-171-172 N-5 (1925) 1926 Yakut-1-2
116, 121, 134

"The country visited may be divided into two regions: the plateau on the south, and the mountain chain on the north. A short account of the geology and geomorphology of each will be followed by a description of the soil covering of the whole country visited, both being the results of the investigations carried out by professor A.A. Grigoriev and his assistants in the summer of 1925."

1. Aldan plateau

Beginning with the geology and the geomorphology of the Lena-Aldan plateau it should be mentioned that the plateau owes its name to the river Lena and its largest right tributary the Aldan, and occupies the area limited on the west by the former and on the east and north by the latter The object of the party was to investigate the north western part of this plateau, which has been more than once visited by explorers. They have, however, left but very scanty records of their observations in this country beyond general statements upon the land surface consisting of Quaternary sediments and presenting a very uneven configuration. Such a paucity of records of former investigators is largely due to their having all rapidly traversed the region, in most cases during the winter or early spring, while the ground was still covered with snow and they could travel more expeditiously and comfortably in sledges. [172]

28: Grigoriev--171-172 N-5 (1925) 1926 Yakut-2
116, 121, 134

The author (prof. A. A. Grigoriev) succeeded in traversing the Lena-Aldan plateau in the following directions: 1) from Uly-Ary (on the Lena 40 klm below Yakutsk) to the NNE as far as the Dygdala left shore of the Aldan (opposite the mouth of its tributary the Kel (a distance of 185 klm); 2) from the Aldan, somewhat west of the mouth of the Kel to the N as far as the Tumara (a distance of about 60 klm); 3) from the Dygdala shore to the East as far as the mouth of the Tanda, and 4) from the village of Tanda along the so called old Verkhoyansk post road to the S and SW on the way back to the village of Yarmonka, situated on the right shore of the Lena, opposite Yakutsk."

28: Grigoriev--172-176 N-5 (1925) 1926 Yakut -1-7
116, 134

"In summarising all the information collected by the members of the expedition in the course of their field investigations on the plateau, the following sketch of the leading characters of its geology and relief, as far as it alludes to the north western part visited, may be presented.

The plateau is exclusively formed of loose sediments. They overlie a stratified sheet of gravel and coarse sand, disposed in regular layers or in lenticular shape, usually of a rusty red hue due to the presence of iron oxides.

The pebbles of this suite are composed of various sandstones, granite, light yellow quartzite, porphyry tuff, hornblende andesite, other andesites, quartz hornstone, contact hornstone--all rocks which are not encountered in the adjoining parts of the Verkhoyansk mountain Range, and for the origin of which partly the Stanovoy Mountain chain or possibly the crystalline mass of the region of the upper Aldan must be sought for. The arenaceous horizons of this series often exhibit a very well expressed cross bedding. This series in general presents a very great similarity with Upper-Jurassic conglomerates and sandstones, exposed on the surface of the Lena-Aldan plateau somewhat to the south of the latitude of Yakutsk, where their superficial horizons not infrequently appear also to be of a loose texture. On the other hand, they very much resemble the Upper-Jurassic conglomerates of the Viluisk basin which, according to the researches of V.N. Zverev and A.G. Rzonsnitski, (1) represent a gold bearing formation and are

1. See Izv. Geolog. Com Vol. XXXVI. 1917.

sometimes described as being 'loose con-[173] glomerates.' It is much to be regretted, that a lack of suitable apparatus prevented the author of this volume from throwing more light on the gold bearing capacity of these deposits in the region under discussion, but there is in any case much probability that they are of Upper-Jurassic age. These strata are exposed in sections on the Aldan, both opposite the Dygdala shore, and near the mouth of the Tanda, as also in the low lying ground bordering the latter. They are likewise exposed 40 klm south of Dupsun. They may thus be regarded as being widely distributed over the whole region, although in view of the absence of deep sections rarely disclosed. They underlie layers of dark grey sand interpolated with clays of the same colour; here, in the lower horizons at least, are present intercalations of half decayed plants, which are always found deposited upon sand and covered with clay. As determined by V.N. Sukachev these remains belong to a stage not earlier than the Interglacial, more probably to the Preglacial, with a climate similar to that of the present day. To the NE of the region visited this series is not remarkable for thickness, as the major upper part of it is replaced by thick layers of very coarse gravel, which may be characterised as exhibiting an exclusive prevalence of sedimental rocks of the Verkhoyansk type. These beds of gravel are well developed on the Aldan, both opposite the Dygdala shore, as well as somewhat further north on the Tumara. Their thickness increases towards the N, as may be seen by their being under 8,5 m on the Aldan, while, without taking account

of the layers which are buried below the water level, exceeding 15-17 m on the Tumara. In the region of the Tanda they are replaced by an argillaceous sandy formation of a thickness of up to 25 m (it being only 2, 3 m thick in the Dygdala region), the clays in its upper horizons becoming slightly carbonaceous and assuming a brown colour. These deposits extend far to the south, and their upper horizons become exposed on the right shore of the Lena somewhat below the latitude of Yakutsk (10 klm below Yarmonka); they have also been observed on the lower reaches of the Tanda.

The stratified series just described, as well as the thick gravel layer which supplants it, underlies, the first on the E and SE, the second on the NW, a thick sheet of unstratified loam generally carbonaceous, with local inclusions of vast boulders of fossil ice, which reach a thickness of 25-30 m, the loams possess-[174]ing a still greater thickness. Towards the west the loams are replaced by unstratified sands.

The above mentioned boulders of ice are of a granular structure, filled with air vesicles, and devoid of any stratification. Externally they fully resemble the fossil ice of the more northerly tracts of the Lena basin, usually regarded as firn ice and formed of extensive motionless accumulations of snow of the Glacial age. The bones of the mammoth occurring in the region described, as well as in more northerly districts, are generally found in the exposed strata containing these boulders of ice. It is remarkable that these boulders of fossil ice are usually deposited in the more elevated parts of the present relief. On the extreme NW of the region under consideration (on the Tumara)

the loams that envelope the ice lose their carbonaceous character and are represented in two varieties: the upper sheet (1, 5 m)without traces of stratification, and the lower, in immediate contact with the ice, in which thin (3-5 mm) intercalations of loam are interposed with yet thinner seams of ice. This second variety is most abundantly developed in the spaces intervening between the boulders of ice, i.e. in the fissures of firn ice, which have been subsequently filled with sediments deposited by waters caused by melting ice and snow.

In all other cases the loams (carbonaceous) exhibited no stratification, and if such in rare cases was present it was never disposed horizontally. Sands, which replace the loams on the west (in the Lena zone), attain a thickness of 40 m on the banks of the Lena, where they are of a greyish yellowish colour, gradually becoming grey further east. These sands dip under the loams in the E and gradually wedge out. That such is the case may be inferred from the country rock banks of the ancient Lena valley being almost exclusively formed of these sands, whereas the sands overlying the loams on the Aldan opposite the Dygdala shore are but 9 m thick and completely disappear from sections at the mouth of the Tanda.

While between Uly-Ary on the Lena and Dygdala the sands rapidly disappear under loams, further south on the Verkhoyansk post road the case becomes more complicated:

along the route from E to W wide bands of carbonaceous loam alternate with narrow sandy ridges until further W on approaching the Lena the sands become the dominating rock. [175] Throughout the route the sands may not unfrequently be observed to be superimposed by sheets of loam. Yet the height of the ridges, however composed, undergoes little change. Whence follows the obvious conclusion that the sands exhibit a markedly undulated surface. It should also be observed that both in the region of the exclusive prevalence of sands, and also in spots where they emerge but as solitary ridges, occasionally in depressions and on flat areas, the sand is covered by a thin layer of carbonaceous loam, several decimetres thick, reposing on a similar layer of slightly carbonaceous sandy loam; or the two latter layers may be represented by the sandy loam alone.

The above indicates that a continuous loam mantle which was removed by denudation was here formerly present.

The sediments described above and deposited on top of Upper-Jurassic loose conglomerates (gravel and sand) appear to be of Quaternary age, while the lower horizons of the sandy-argillaceous suite with intercalations of plant remains should be relegated to the Preglacial age, the intermediate strata to that of the Primary glaciation, and the top layers (with interpolations of brown carbonaceous loams) to the Interglacial epoch. The upper gravel beds, replacing the intermediate and upper horizons of the argillaceous sands, should be assigned to the Interglacial, and also very probably to the Primary Glacial epochs. To these same Interglacial deposits probably belong the sands bordering

on the Lena, which replace the upper gravel horizon on the west, whereas the fossil ice with its enveloping mantle of carbonaceous loam, as well as the carbonaceous loams and clays in general are of the most recent Glacial age.

The gradual substitution of the sandy clay horizons by the gravels of Verkhoyansk origin on the N is most probably connected with the erosion of the moraines of the Primary glaciation, which has culminated in the production of boulders.

The development of the stratum towards the NW seems to indicate that the Verkhoyansk mountain glaciers, owing to the discontinuous character of the Verkhoyansk mountain Range had here a freer access to the S, whereas in the eastern direction, where the Yakut mountain Chain separates the Verkhoyansk uplands from the Aldan plateau by a continuous barrier, that Chain offered a very serious obstacle to the motion of the glaciers, beeing at the same time too steep and narrow to afford [176] the necessary conditions for an extensive development of its own system of the latter. Thus, the glaciers of the Verkhoyansk mountain chain have amassed their terminal moraines at a greater distance from the Chain in the western, than in the eastern direction, as is exemplified in the region of the Tukulan.

The country in the Interglacial age, and most probably in that of the First glaciation, as also in the time immediately preceeding it, represented on the whole an extensive lake basin, on the bottom of which was deposited the series of sediments described above. The

presence in the upper layers of this stratified series of carbonaceous clays interpolated with sand indicates a notable shallowing of the basin prior to the arrival of the last Glacial epoch."

28: Grigoriev--176-181 N-5 (1925) 1926 Yakut -1-8
116, 133

[LSS: For a discussion of the area analysed, see category 134, pp.171 ff.] In its geomorphological aspect the forms of relief of the Region described may be characterized as being of three types: that of a hilly country studded with lakes, of a hilly country intersected by valleys, either of these in various modifications, and, lastly, as that of the valley type alone. The most usual and characteristic form of relief of this region is the first of these three, particularly well developed in the southern part of the region visited, and constituting a wide belt down the right bank of the Lena, as well as similar belts extending in a northerly direction. One of these belts lies along the meridian of the Dygdala shore, whilst another runs nearly along that of Borogontsy. The first is even continued beyond the north bank of the Aldan, although interrupted by a rather narrow belt of hilly valley country. Between these belts extend zones of this latter type, likewise disposed in a meridional direction. A zone of that kind stretches to the east of the Borogontsy hilly country-lake zone, and yet another similar one is apparently situated between the just mentioned Borogontsy and the Dygdala-Dupsun hilly country-lake zones, although it is better developed as it approaches the Aldan, extending but little to the south, so that at this spot all the three belts of the hilly country-lake type merge together. It is very difficult, however, to give an exact account of the distribution of these types of relief in view of the absence of a topographical survey of the whole country. According to oral information derived from local sources and to field sketches of the maps of the

naslegs (minor administrative units) of the Borogon- [177] ski ulus (a major administrative unit) in the eastern part of that ulus the lakes are much less numerous than in the western: the hilly-valley and the pure valley type of relief evidently predominate in the eastern part, although the general surface of the country is here considerably flatter than in the west.

The principal axis or backbone of these hilly-lake belts may be characterized as exhibiting the greatest degree of dissection of the relief. The height of the ridges, or, which comes to the same thing, the depth of the depressions, reaches here 50-60 metres, the ridges between the depressions being often very narrow, sometimes not more than 50-100 m wide, their sides steep, the tops of the ridges being flat or hilly. The depressions extend over a larger area than the ridges. Their bottoms are generally filled with lakes, which in this part of the country acquire their greatest dimensions. In this 'backbone' region of the hilly-lake belts the lakes in general completely fill up the bottoms of the depressions, although not infrequently containing islets which emerge above the surface of the water; the cases are less frequent when the lakes occupy the deeper parts of the depressions only. The shape of these lake depressions is not uniform: thus, in the region of Borogontsy the lakes are mostly all but circular, in the zone of Dupsun they are very generally of an elongated form; long inlets of water disposed as a rule along the meridian with a slight deviation towards NNW or NNE are still more frequently found in the latter zone, of which these inlets are particularly characteristic; they often abut upon

steep cliffs, which form closed amphitheatres. No less characteristic of the lakes in this belt are slightly curved land spits, which extend far into the lake, especially at the entrance to the inlets described above, the channels to which they obstruct. The great majority of the lakes of the 'backbone' region of the hilly-lake zone possess no perennial outlets; if ever such are provided they represent beds, situated at a considerably higher elevation than the summer level of the water in the lakes. In spring, when the level of the water in the lakes rises (according to local information to a height of 2 to 6 m) a discharge of the water may frequently be effected. In the majority of the lake depressions examined, however, no vestiges of a drainage of any kind could be observed; at the same time in many of the lakes the water is of a sufficiently unpleasant taste [178] to suggest the initial stages of its becoming salt. Judging from local information, however, true salt lakes in this region are extremely rare. It should be added that the lakes of the zones described are usually situated at various altitudes and the difference may amount to 20 metres, although generally not so much. The zones described usually represent watersheds and are not traversed by streams or watercourses of any size. The relief both east and west of the 'backbone' gradually flattens out. This flattening consists in the gradual decrease in the height of the ridges which do not exceed 10-20 m of absolute altitude, their width at the same time very much increasing; the number

of lake depressions slowly diminishes, although remaining pretty considerable; on the other hand, depressions covered with meadow occur more frequently, a few puddles alone remaining from the former lakes. The number of lakes with islands in their centre, more often flat, sometimes in the shape of slight eminences, with well defined cliffs, increases. The steep cliffs of these lake depressions become lower as these latter are further removed from the 'backbone' of the zone in question, dropping to 3-5 m in height, instead of 40-50 m, as is the case in the region of the 'backbone', and eventually disappearing altogether, being supplanted by very gentle slopes. These lake depressions, as well as the lakes themselves also diminish in size, while the beds of the lake outlets, like narrow creeks, generally dry in summer, become prominent. Lakes without any outlets, however, occur here also. Finally, small streams, although not often, appear: some of them look normal enough and flow in well worked out meandering valleys, while others (which are met with more frequently) consist of a chain of lakes, connected with each other by channels, which, when the water level is low, dry up in summer.

It should be noticed that the effects of the different component parts of the subsoil (clay or sand) on the structure of the relief, if observable, are restricted only to minor details. Evidently the permanent ice which equally consolidates clays and sands renders both these rocks nearly identical in the effect they have upon the moulding of the relief. It is remarkable, that no transition zone exists; between the valley of the Lena proper

and the contiguous hilly-lake zone, in approaching the steep country rock margin of that river's ancient valley, the hilly-lake belt abruptly terminates. This circumstance is especially [179] worthy of notice, as the valley of the Lena is 40-60 m deep, so that all the conditions requisite for the development of receding erosion from the side of the river seem to be in evidence. Yet, signs of erosion, as a matter of fact, are totally absent, and this may be accounted for on the one hand by the frozen state of the sands, and on the other by the rain and spring waters being completely absorbed by the numerous lake depressions of the plateau, which, in connection with the powerful summer evaporation, part with a great quantity of water, and never being full to the brim, are unable to produce water courses flowing in the direction of the Lena. The river valley of the Lena seems to be of quite recent age in this district (1) and could not be formed prior to the

1. This observation must not be understood to refer to the age of the Lena valley both above and below the region of the Pre-Verkhoyansk depression, which in the beginning and middle of the Quaternary period was a lake, into which the Lena fell and from which it flowed out.

disappearance of the dislocated basin, bordering on the Verkhoyansk chain from the south, which was filled up by sediments of Quaternary age.

Conversely, the eastern slope of the hilly-lake belt bordering on the Lena and inclining towards the Tanda river valley, bears all the marks of a transition hilly valley relief.

True, the fllattening [sic] of the relief analogous to what has been described of the western border of the Lena zone may be observed here also, the number of depressions occupied entirely or to a great extent by meadow increases here just as much, but these depressions differ in being connected together by narrow gorges with a slightly concave bottom along the central line, their lowest parts being overgrown with belts of reeds, while to the right and left extend bush-like growths of the stunted birch Betula Middendorfii and B. fruticosa. The old shore lines of these valleys are well expressed and, though not high (2-3 m), are fairly steep. It is characteristic of these valleys, that the dip of the bottom is conspicuous enough to be visible and is usually inclined towards the nearest depression, so that one section of the valley has a fall in one direction, the other in another, the central piece being occupied by the watershed of the valley. In rare cases, a miniature recent gorge, in summer as destitute of water as the valley itself, may be observed to be cut into the [180] flat bottom of such a valley. In spring these valleys are naturally full of spring waters, to the action of which they owe their origin.

North of Aldan throughout a distance of ten kilometres from the old shore lines of the ancient river valley, nearly opposite the Dygdala shore, a type of hilly-valley landscape, allied to the one described above, but possessing original features, is observed

to occur. This section of the hilly-valley 'landscape' interrupts the further development of the hilly-lake relief. Being characterized by wide, nearly dry valleys, similar to those described above, but possessing a greater width, this belt may be further distinguished by the valleys having numerous branches, often ending blindly. Such palmate shaped systems of valleys, with clearly expressed bluffs 3 or 4 m. high, are separated from one another by low valley divides and are not infrequently grouped together around a smooth flat area, forming the bottom of a former lake. Sometimes, especially in the knots of the intersection of such valleys, these latter are studded with pools and lakelets, the level of the water of these latter being flush with the bottom of the valley. It is obvious that we have to deal here with the remains of a system of lakes, which possibly had numerous bays and had been at the same time connected with each other by channels; the filling up of the depressions with sediments and the drying up of the lake system has here progressed much further, than had been the case with the first of the hilly-lake regions described, to which the presence of a narrow, but sufficiently deep valley, cutting through the neighbouring high bank of the Aldan and providing the drainage for the locality described, may have contributed; by these means the lake depressions had lost their water, and the spring waters which accumulate in the above mentioned systems of palmate depressions possess a free access to the Aldan.

28: Grigoriev--176-181 N-5 (1925) 1926 Yakut-8
116, 133

A third variety of the hilly-valley relief may be found on the eastern gently sloping declivity of the Borogonsk hilly-lake belt. The hilly-valley relief is here modified in the lakes (often elongated) being grouped together in common wide valleys, bordered on the right and left by high ridges, while the divides between lakes become much lower; the latter lose in height in the direction towards the E, and ultimately fall to an elevation of a few metres; these divides are mostly cut through by the valleys of small narrow channels, which connect series [181] of lakes into one system. Further E the size and the number of lakes diminish, and the valleys becoming somewhat narrower tend to resemble those described N of the Aldan (i.e. the second variety of the hilly-valley relief): they represent beds dry in summer, with fairly steep country rock margins of about 5 m high, with numerous branches, often terminating in blind amphitheatres, bordered by steep walls; the beds of the principal valleys are now and then studded with pools and small lakelets, the level of the water being flush with the bottom of the valley. Still further E the relief is modified anew and a belt of wide and flat depressions, sometimes possessing lakes, but oftener their remnants only, or being wholly destitute of them, are encountered, these depressions being connected together by narrow, dry (in summer) valleys, by means of which they are joined with the valley of the Tanda; this variety of hilly-lake relief is similar to the first described above.

The third type of relief-the valley type-is expressed in its purity in districts traversed by considerable streams: in the region under discussion such streams are the Lena, Aldan, Tanda and Tumara."

28: Grigoriev--181-185 N-5 (1925) 1926 Yakut-1-6
116, 133

"The valley of the Lena is bordered on the East by a high main bank (40-60 m high), which occasionally has an abrupt drop to the flood plain below lying at an altitude of 4 m. above the river, but is generally skirted by two terraces lying at a height of 10 to 15 m above the river flat. Not infrequently these terraces widen out to a very considerable extent affording sufficient space to be occupied by villages and arable lands. Both on the bottom lands, and on the terraces immediately above them occur (in the vicinity of Yakutsk) small circular marshy lakes containing flat islets, or loop-shaped cut-offs surrounding somewhat more elevated islets. Here and there these islets bear signs of being cleft by deep fisures which extend along their longitudinal axies. The origin of these fissures, as well as of the flat islets is due to the vigorous freezing of the soil.

The valley of the Aldan possesses also extensive bottom lands with cut-offs. The height of the old shore lines reaches 60 m. and more. Two high terraces are present: one at an altitude of 15-20, another at that of about 30 m. The latter is frequently very much eroded, leaving remnants in the shape of the residual detached hillocks and ridges.

[182] The height of the bluffs of the Tanda and Tumara seldom exceeds 30-35 m. Both rivers have made relatively deep cuts in their flood plains, the first to a depth of 6-8 m, the second--4-5 m. Residual hillocks and ridges, 8-10 m high above the river flat, is all that remains of the terrace skirting the latter.

The above features relating to the relief may be supplemented with certain particulars connected with the universal prevalence in the region of permanent and fossil ice.

To these particulars belong; 1) a very slight dissection of the steep declivities by ravines and gullies, which although occasionally present, and, of an insignificant length, may attain a considerable depth; a slight development of the receding action of erosion can only be explained by the frozen condition of the ground; 2) a peculiar microrelief of the steep clay banks, which seem to be studded with oval excrescences, formed at the expense of separate sections of the declivity being cleaved off by fissures caused by frost, and which thaw out in spring and form landslides; 3) peculiar, deep cirques or amphitheatral recesses formed at the points of the most intense thawing of exposed boulders of fossil ice aud [sic] being often nearly closed and having as points of outlet but very narrow gullies.

The form of the relief of the region described is thus a hilly-lake landscape, which at times strikingly recalls typical landscapes in Finland; this resemblance is especially great in the region of the prevalence of sands with their growth of pines. This resemblance, which suggests the glacial origin of the relief of the northern parts of the Aldan-Lena plateau, fails, however, to accord with the fact that, whereas in Finland the forms mentioned are situated between the centre of glaciation and its outer limits in the shape of terminal moraines, here the terminal moraines of the glaciers, which have descended from the Verkhoyansk mountain chain, are disposed much nearer to the chain and consequently the part of the plateau visited could not have been covered by them. On the other

hand, the cirques described above in the shape of circular depressions with steep sides, which at present are occasionally formed where boulders of fossil ice become exposed and melt, suggest the idea, that the lake depressions of the plateau are genetically connected with the processes of the formation of such cirques.

The researches of J.P. Tolmachoff and Vollosovich on [183] the fossil ice of the more northerly regions of the Lena basin have established the fact, that we have here to deal with masses of motionless firn, produced from snow, which appear to have accumulated in the depressions of the relief since the Glacial age. The complete resemblance in the structure of the boulders of the fossil ice of the Lena-Aldan plateau studied by the author with that described by the above mentioned investigators, compels us to admit that the fossil ice of the region under discussion possesses a similar origin and had arisen in the same age. The conditions for the accumulation of ice in the northern part of the Aldan plateau must have been very favourable at that time, as a depression was present, which although filled withthe stratified sedimental deposits of Quaternary age described above, undoubtedly yielded in height to the surrounding country. In the epoch of the most recent glaciation vast motionless firn fields thus extended south of the terminal moraines of the Verkhoyansk glaciers, and were strewn over with dust and silt by summer waters and wind. These sediments may have been carried not only from the north, but possibly in a greater measure from the south, where at that time reigned an arctic desert or

semidesert which afforded a wide scope for vigorous processes of weathering. It is not in vain that a sheet of loess loam extends far south over the plateau. That the firn fields were strewn over with particles of dust may be proved by the fact recorded by D. I. Melikov, an old inhabitant of the place fully worthy of credit, that a piece of fossil ice from an exposed section on lake Muru near Borogontsy, on being melted, produced a considerable quantity of fine brown clayey sediment. Still it must be admitted, that during the epoch of the most vigorous accumulation of firn the conditions for its being covered with drift could not be very favourable, as most of the latter must have accumulated in fissures and other depressions during the summer thawing of the surface of the firn fields, where it was deposited, often obtaining a stratified character, being frozen through and interpolated with thin layers of freezing water.

The process involved in covering the firn fields with loesslike loams and sandy loams and, in proximity to the Lena, originally with sands, must have been more vigorously carried out since the commencement of the recession of the Verkhoyansk glaciers, at which period the moraine drifts of these latter become exposed [184] and rendered more accessible to the action of running water and the wind, while the changes in the conditions of the climate could not but contribute towards increasing the bulk of sediments carried from the south. As the more prominent parts of the firn fields at that time commenced to thaw more vigorously, the sediments that had settled down on them must have been carried away, accumulating in the lower parts of the firn areas and

forming a mantle sufficiently thick to be able to protect the ice, buried beneath them, from thawing through the effect of the sun's rays.

These sediments had of course accumulated also in great quantities on tracts free from the firn covering, and presenting favourable conditions for that purpose.

Thus, owing to the protection afforded by these sediments during a considerable period of the recession of the Verkhoyansk glaciers the ice to the south of the Range did not disappear. The process of elimination of the ice had been retarded for a very considerable period and, as we have just seen, is not even yet over, in spite of the high summer temperatures of the present climate. Parallel however to the accumulation of the deposits described above, as soon as the climate began to change and to cause a vigorous recession of the Verkhoyansk glacier, separate boulders of firn ice more prominently protruding above the surface of the plateau, as they became sufficiently exposed to the action of the sun's rays, commenced, as we have seen, to thaw out. In such places were formed cirques of the kind described above increasing in area, and at length attaining the size of the present lake depressions, while the lower tracts of the firn fields, protected by deposits of sediment, remained very little altered and became gradually transformed into ridges, separating the lake depressions from one another; in such cases sheets of loam sliding down from above not infrequently could protect the ice walls, about to be exposed, from melting by enveloping them anew. Tracts, where

sediments accumulated on the ground and not on the firn, also naturally gave rise to ridges. The water, formed from the melting of the ice and accumulating in the growing cirques did not fill them to the margin through loss by excessive evaporation caused by the extreme aridity of the climate, which undoubtedly prevailed here towards the end of the Glacial Period. Thus, ever since the end of that period [185] and to this day thousands of closed lake depressions without outlet have been formed one after another on the site of former firn fields. Occasionally, in spots where the external conditions were favourable for that purpose and suitable sources of erosive activity were present, as in the neighborhood of large river valleys, these lake depressions were subject to further changes and the hilly-lake relief became transformed into one of a hilly-valley character.

According to inquiries from old inhabitants of the country made on the spot fossil ice seems to occupy considerable areas in the nothern [sic] parts of the plateau.

However that may be, it cannot be denied that this country has at the present time reached a stage which has been passed by the European North, although in a somewhat modified form, many thousands of years ago, and which corresponds to the latest periods of glaciation."

28: Grigoriev--185-190 N-5 (1925) 1926 Yakut-1-8
116, 133

" II. Verkhoyansk mountain range.

Summarising the observations made in the region traversed by the Verkhoyansk-Tukulan road and lying east of the latter between Sartang on the one hand and Nyalgyakha River and Hongkui mountain on the other, a short account of the geological structure and geomorphology of the Verkhoyansk Range and of the southern border zone, situated north of the Aldan, may be given as follows.

The Verkhoyansk Range is formed of steep, somewhat assymetrical folds, closely pressed together and sloping generally in a NE direction, and is usually of a small transverse diameter of 2-5 klm. The direction of the strike of the rocks, as also of the folds, is characterized by its exceeding complexity in this region; on the southern border of the folded zone it approximates to NW, ranging between N 316° W and N 336° W, while on its southern limits in the Mollegoi hills it is N 339° W, in the Yakutsk Chain N 316° W and near Urlachi R. N 334°--344° W. In closer proximity to the mountain pass over the principal dividing ridge of the range, north of the mouth of Longitudinal Tukulan the direction of the strike ranges from NNW to an all but meridional position (from N 334° W to N 350° W); in the vicinity of the Jugjur Pass and of the northern slopes of the range the strike assumes a meridional direction varying from [186] N 356° W to N 4° E; further

north, on the Upper Kieng-Uryakh (Upper Yana) it reverts to NNW (from N 339°W to N 349°W) only to assume anew a meridional position (N 354°W and 6°E) further down that river; in one place, however, the strike was found to be N 344° W. In closer proximity to the confluence of the Kieng-Uryakh with the Sartang the strike again assumes a NNW direction (N 338° W to N 346° W), and again occasionally reverts to a meridional position (N 339° W to N 354° W) in the region of a section of the Yana called Sartang (north of the Kieng-Urgakh Chapel). East of this region between the valleys of the Yana (Sartang) and the mountain pass towards the Nyalgyakh valley the predominating direction of the strike is intermediate between NNW and NNE (N 344° W--N 8° E), only to range between NNW and a nearly meridional direction in the basin of the upper Nualgyakha (N 348° W --N 355°). The variation of the strike of the folds is thus tolerably uniform in the country visited and refers equally to the direction from the S to N as to that from W to E, these being the alternate routes followed by the exploring party. If this general statement be confronted with the fact of an apparently greater variation in the strike in separate sections of the route, when a tendency to assume a direction to the NE (N 49° E) or even ENE (N 69° E) may be observed, the conclusion is necessarily reached that the folding here must be very complicated and that either vertical bendings of the axis of the folds in regard to their strike, or else horizontal torsions in a direction transverse to the strike, or both, are here met with. It is to be regretted that owing to a very cursory

examination of these phenomena, incidental to the restricted time which was at the disposal of the author while crossing the Range, it was impossible to come to a more definite conclusion on the subject. However, it follows from the above that there is no serious ground for opposing the NW strike of the southern parts of the elevated tract under discussion to the NE strike of its more northerly portions, as is insisted upon by some authors, who attribute a different age to each of these foldings by referring them to deposits of various epochs. By this, however, the author does not mean to imply that the folding processes that have occurred here should be necessarily attributed to one and the same age.

The rocks which constitute the Verkhoyansk mountainous tract [187] are not conspicuous for diversity. The mostly consist of arkose sandstones, interstratified with finely grained sandstones, externally approximating to argillaceous schists, both locally containing a certain quantity of lime.

In some regions sandstones predominate, in other schists; thus, in the Yakutsk chain schists are nearly absent, and horizons of conglomerates occur in the midst of sandstones; conversely, the western slope of the divide between the systems of the Tangkhalakh and Nyalgyakh is composed all but exclusively of schists. Yet it is remarkable, that the arkose sandstones of the Yakut chain and of the adjacent region bordering on the north reappear on Hongkui mountain at the northernmost point reached by the expedition.

Occasionally, these rocks are replaced by dark grey, nearly black, calcareous sandstones merging into hornstones, and by arkoses of the same character, which constitute a massive layer on the south slope of the Dividing Range, and form a continuous zone between Byadya-kuel and the mouth of Longitudinal Tukalan; outcrops of such calcareous sandstones, but extending over a restricted area, occur also on the left bank of the Timirdyakh, directly north of the Yakut chain. Judging from the degree of metamorphism they have been subjected to, the age of those calcareous sandstones is more ancient than that of the remaining sedimental series; by analogy with the calcareous rocks of the more western parts of the Range they should apparently be referred to a Paleozoic formation. The thick layers of arkose sandstones, interstratified with rocks, in character allied to argillaceous schists, should on the other hand, by analogy with samples collected by Toll and Tscherski from other parts of the same Range, be refered to the Trais and possibly to more recent Mesozoic time; the arkoses of the Yakut chain of Hongkui belong here also.

Fossils (remains of plants) have been found by the author in the southernmost outcrops of the arkose-calcareous sandstones alone: although these remains cannot be identified, they should, in analogy to the outcrops of similar rocks on the south of the Lena-Aldan plateau, be Jurassic or Cretaceous. In this very layer have been found seams of productive lignite, evidently of the same age. There is every reason to expect the occurrence of such coals throughout the entire extent of the Range from the Mollegoi

hills to as far as the southern slopes of the Yakut chain, [188] a distance of about 20 kilom., where outcrops of the same suite are found east of Tukulan.

The character of the dislocation of these rocks fully agreeing with that of the mountainous region indicates the Mesozoic age of this last stage of the folding processes, to which in the opinion of V.A. Obruchev, an Upper Cretaceous age may be assigned. On the other hand, the exceedingly intricate character of the dissection of Paleozoic rocks seems to imply the presence of ancient folds, formed at the end of the Paleozoic era. Yet, the strike of the folds does not here seem to differ from that of the Mesozoic formation. At the same time, the abrupt outcropping of rocks collected in folds from beneath sediments, of which the low hills of Mollegoi 40 klm from Aldan and 20 klm from the Yakut Chain are formed, seem to indicate that their southeastern margin is severed off by a fault, down which the territory lying to the south subsided.

There are grounds for assuming that the Yakut Chain north of Timirdyakh is likewise skirted by a fault line, along which basalts were extruded. Finally, the exceedingly sharp and abrupt elevation of the southern slopes of that chain above the flattened surface of the sandstones and schists of the level foothill zone, dislocated conformably with it, leads to the same conclusion, that here also a fault line must have arisen.

In such case the Yakut Chain and the adjacent section of the valley of Timirdyakh should be regarded as having been produced by an upward thrust, the northern parts of which have been deeply indented by a valley, whereby in a zone of Mesozoic deposits Paleozoic rocks have been disclosed.

The Verkhoyansk Mountain Range thus seems to be skirted on the south-west by a belt of fault dislocations running parallel to it. These disjunctive dislocations seem most probably to have been formed in the Tertiary Period, or subsequently to the time when the folded tracts of country had all but assumed the character of a plain with a series of residual eminences.

In the Dividing Range and north of it the author met with no ostensible indications of thrust phenomena.

With reference to the tectonic features of the Verkhoyansk mountainous tract it should be noted that the south-western slope is in general steeper and shorter than the north-eastern, the elevations of the latter gradually diminishing in height and [189] extending for hundreds of kilometers nearly as far as Verkhoyansk; whereas the highest ranges of the whole country, the Dividing Range and Yakut Chain, are separated one from another by but 87 klm at most (as the crow flies), the former range being separated from the southern limits of the folded area by a distance of about 115 klm.

The altitude of the eminences of the Dividing Range in the region of the Jugjur pass reaches about 1800 m, the pass itself measuring 1438 m. The height of the range west of

the pass seems to diminish, while to the east it increases very considerably, although nowhere reaching the line of perpetual snow: in various spots, however, protected from the effect of the sun's rays, tracts and belts of snow persist throughout the summer. The southwestern slope of the Range gradually decreases in height in the direction of Byadyakuel, to the south of which extends a lower belt of an altitude of 800-1000 m, which continues to decline in a southerly direction. The Yakut Range, about 5 klm wide, follows next and after reaching an altitude of 1100-1200 m, abruptly descends to the N, towards the Timirdyakh valley, the bottom of which lies at a height of 400 m; the southern slope of the Yakut Range, although not so abrupt, is steep enough, The greatest heights in the Yakut Chain, as in the Dividing Range, are situated to the east of the Tukulan road (where the Yakut Chain seems to be known by the name of Sordoga), while to the west of that road the Range rapidly loses its identity and splits into a number of separate ridges or blocks, rising directly above the plain.

The Yakut Range, to the left of the Tukulan, is bordered on the south by a low plateau, gently inclining to the S, 400-450 m high, with an all but flat even surface, although formed of rocks of Jurassic (possibly Cretaceous) age, which are collected in folds.

West of the Tukulan this plateau is buried under a layer of sediments constituting a vast accumulation of terminal moraines of an altitude of 315 m above sea level. At some distance south of this the plateau can be unmistakably recognized on both sides of the

Tukulan, forming at the same time the Mollegoi hills which extend across the river and rise some 10-20 m above the neighbouring country. Still more to the south moraine accumulations may be met with 20-30 m above the Tukulan, generally forming narrow ridges disposed in a latitudinal direct-[190] ion; they are also more or less well expressed in the moraine landscape north of the Mollegoi hills."

"North of the Dividing Range the mountainous country, as has been shown, very gradually diminishes in height. Receding somewhat from this Range two ancient elevated surfaces of denudation may be observed, the lower of which lies 100-150 m below the higher and is represented now by broad, flat summits, while the latter possesses more sharply indented ridges. In the region of the Yana (Sartang) this lower surface of denudation lies at an altitude of 1100-1150 m, in that of Tangkalakh R. at 1300 m, and in that of the sources of Nyalgyakhya R. at 1300-1350 m. In closer proximity to the Dividing Range this lower surface of denudation covers relatively small tracts, which skirt the valleys, whereas northward it is spread over ever increasing areas at the expense of the more highly elevated denudated surface, until still further north this latter is completely superseded by the former.

The upper denudated surface, although occasionally exhibiting a markedly disjointed and consequently somewhat disturbed relief, is also not unfrequently varied by the occurrence of flat surfaces studded over with protruding ridges and summits of a more or less sharp outline, to which it forms a pedestal.

The ancient lower denudated surface seems to have been formed by the processes of erosion and denudation, due to an activity heightened by the upheaval of the country above its former level, which was then considerably lower than it is at present. In no other wise can be explained the rapid development of these processes. On the southern slope of the Range very little has remained of these denudated surfaces; possibly the most

extensive of these remains is the folded residual plateau lying to the south of the Yakutsk Chain.

Such a difference in this respect between the southern and northern slopes of the mountainous region is connected among other things with the vast preglacial upheaval of the latter having caused a rapid dissection of the relief; and, as a matter of course, this process has gone much further on the steep southern slope and has there effaced the major part of the former surfaces of denudation, whereas on the gentler northern slope it has been restricted to the deepening of valleys. Intervening glaciation has produced the least effect upon the second [191] surface of denudation, which appears at that time to have been covered with firn fields and ice of the Scandinavian type; whereas the river valleys, transformed into beds of mountain glaciers, had under the influence of the latter unrecognizably altered their character. The activity of ice has powerfully affected the forms of the relief of the Dividing Range, the then centre of glaciation. All the ridges and slopes of this Range bear a purely alpine character: occasionally glacial 'karrs' occur on its highest summits.

No less characteristic are the river valleys in the shape of typical troughs with wide bottoms, in no wise corresponding to the breadth of the present river beds, with nearly vertical sides, hanging valleys of their minor tributaries, and steep alluvial cones. Particularly striking is the very deep depression of the valleys, in consequence of which the rivers, even in their uppermost course, in spite of the rapidity of the current (the

fall being about 10 m to 1 klm), are unable to effect any deepening erosive activity. As a result of such conditions the rivers deposit sediment in their upper reaches and break up into channels, exhibiting phenomena usually characteristic of their lower course.

The same causes produce a very considerable swamping of the valley bottoms, as these latter are but very indifferently drained by the rivers running down them. The extensive development of glaciation in the Verkhoyansk mountain region is manifested besides in the wide distribution of boulder loams and sandy loams over both the valley bottoms and the elevated surfaces of flat ridges. Finally, in the valley of Tukulan, and in those of the northern slopes, evidence is universally afforded of the remains of the glacial bed bottoms forming elevated terraces of native rocks with an undulating surface, not infrequently covered by a moraine mantle. Of such terraces there are generally two, which in the Tukulan valley lie at an elevation of 20-40 m and 70-100 m respectively above the water level of the river; in the valleys of: Kieng-Uryakh at 7-15 m and 35-40 m; Tangkhalakh at 3-5 and 100-130 m, and Nyalgyakh at 7-15 and 40-50 m.

The above leads to the conclusion indicated by some observations made earlier, that these valleys were subject to no less than two epochs of glaciation. It may be noted besides that in the Tukulan valley typical 'riegels' occasionally occur (especially [192]

in the region of the distribution of dark grey calcareous limestones) and in the valleys of the northern slope transverse 'troughs' are not infrequently very well developed. All the mountain passes visited by the author represent the results of the activity of the glaciers, or rather of their lateral branches passing over the ridge into the neighbouring valley. Many of these passes contain small lakes of an undoubtedly glacial origin. As the route of the author did not extend beyond the region of glacial phenomena, he was unable to ascertain its northernmost limits; judging from the observations of other explorers it may spread as far as the ocean. As regards the southern slope the terminal moraines were found by the author to lie immediately south of the Yakutsk Chain on the one hand and between the Mollegoi hills and the Aldan on the other. These last may be distinguished from the first not only by possessing less typically prominent forms of relief, but by the horizon containing boulders on elevations underlying a thin (40 cm) layer of boulderless loam, similar to that which is widely spread over the Lena-Aldan plateau south of the Aldan, where it cannot but be regarded as a formation deposited during the period of the most recent glaciation. These circumstances afford full grounds for looking upon the moraines accumulated between Mollegoi and Aldan as a terminal moraine of the first glaciation, while a similar accumulation adjoining the southern foothills of the Yakutsk Chain and bereft of the boulderless mantle may be regarded as terminal moraines of the second glaciation.

Thus, the geological history of the Verkhoyansk Range, in so far as it can be ascertained, may be presented as follows. The area of the future Range was originally collected in folds at the end of the Paleozoic era, when it first became land. After a considerable period of denudation it was invaded anew by the sea, when Mesozoic strata were deposited upon its surface. At the end of the Cretaceous (?) period this region was subjected again to an intense process of folding, resulting in a relatively low, folded mountainous tract, which slowly emerged from beneath the level of the sea. A continuous alteration in the direction of the strike of Mesozoic rocks shows that the folding was not only caused by the pressure of the masses of ancient rock, situated to the N and S of the Range, but hindered in its free development by the resistance afforded by similar masses from W and [193] E. Meanwhile, the Paleozoic strata underlying the base of the Mesozoic deposits of the Range in consequence of this second period of contortion became very much disjointed in three different directions by fissures, which tended to mask the true direction of the strike of the rocks.

The period of folding processes, at least throughout the area of the southern slope and of the foothills of the Dividing Range, was followed by a series of faults. As a consequence of these latter arose the heaved block of the Yakut Chain, as well as the vast depression south of the Mollegoi hills, extending from that Chain to the outcrop of

28: Grigoriev--190-194 N-5 (1925) 1926 Yakut-6
116, 133

Mesozoic (apparently Jurassic) country rocks of the Lena–Amga plateau, situated in a lower latitude than Yakutsk. The work of erosion and denudation, by which in the meanwhile the Range was moulded, had also given rise to a surface of denudation, very much resembling a plain with residual elevated summits rising above it. In connection with a renewed upheaval of the country a softly rolling denudated surface had widely spread over the area lying north of the Dividing Range and in the shape of separate tongues (corresponding to the respective river valleys) had cut its way into the more elevated parts of the Range; on the south, this surface is represented by a flat folded residual plateau extending from the Yakut Chain to the Mollegoi hills. This period was followed by a new upheaval or a notable acceleration in the elevation of the old, which caused the rivers to cut their beds deeply into this second denudated surface. Towards the end of the period of upheaval the Range was subjected to glaciation, in consequence of which the more elevated parts of it assumed alpine forms. In the meanwhile, the tracts of the second denudated surface lying at a lower elevation, at least in the region of the higher parts of the Range, were buried beneath the ice of glaciers, with which the neighbouring valleys were filled. These glaciers cleared the denudated tracts of ancient sediments, with which they were covered, locally enveloping them with their moraine deposits, and transformed the more or less oblique slopes by means of which these tracts were joined to the more elevated parts of the mountains, into precipitous, frequently all but vertical walls. Judging from the traces that can still be observed the

glaciers of the First Glaciation reached a thickness of 350 m above the level of the valley bottoms in the Yana valley and of 100 m in that of Kul Tangkalakh; the thick-[194] ness above the denudated surface was thus not great, scarcely exceeding 150 m in the region of the Yana, and 30-50 m in that of Tangkalakh, whence their eroding power could not here have been very considerable. Conversely, in the regions of the preglacial river valleys themselves, where the ice had reached its relatively greatest thickness, and the character of its motion was different, its action was very powerful, in consequence of which these valleys underwent the most violent changes.

The process of glaciation seems to have been repeated twice, an interglacial period intervening, as is evidenced by the presence of two systems of elevated undulating terraces (former beds of glaciers) as well as of two belts of terminal moraines at the southern base of the Range. After the end of the Last Glaciation the beds of rivers had somewhat, although but very slightly, cut into the bottom of the glacial valleys, subsequently to which, however, these rivers had obtained senile features in their upper reaches.

The question remains undetermined, whether these latter should not be exclusively ascribed to the energetic deepening of the valleys by glaciers or else perhaps to the postglacial sinking of the mountainous country as well, which last alternative for various circumstantial reasons seems more probable. (1)

1. See Addendum, p. 200."

III. Soils of the Lena-Aldan plateau and Verkhoyansk mountain regions.

In summing up all the observations made on the soil mantle of the regions under discussion the following conclusions have been arrived at:

1. In respect of soils the Lena-Aldan plateau visited by the author may be divided into two parts: one, the western, bordering on the Lena, which may be characterized as having a predominating sandy subsoil, and the other, the eastern part, with an all but exclusive development of carbonate loess-like loams; both soils do not thaw out to a greater depth than 40-120 cm from the surface.

2. Dark coloured (humous) carbonate bearing soils (carbonate alkaline soils of K.D. Glinka), not infrequently leached out in various degrees at the surface, are typical of the carbonatic loams (both in the region of their continuous, as also sporadic, occurrence in [195] the arenaceous zone) of the flat elements of the relief and of the sloping margins of valleys and lakes.

3. The depth at which the soil effervesces with acid (height of effervescence) in the above mentioned carbonatic soils is affected by: a) the relief, b) the position of the locality in regard to the neighbouring mountainous tracts, and c) the depth of the deposition of the permanent ice layer.

4. The depth at which commences the effervescence of carbonatic soils on the flat elements of the relief increases with the proximity of the locality to the Verkhoyansk

Range, gradually descending from the horizon A of the soil (upper) to the horizon B (intermediate) and, finally, falling to that of C (lower) and thus sinking to a depth of about 40 cm from the surface. This progression in the depth of effervescence is explained by the increasing humidity of the climate, as the Range, which may be regarded as the principal local condenser of moisture, is approached.

5. The dependence of the height of effervescence of carbonatic soils upon the relief is chiefly exemplified in the carbonatic horizon ascending to its greatest height at the immediate base of the high banks of valleys and of closed depressions without outlet, whereas on the adjacent heights and in the deeper parts of depressions effervescence commences lower down: the former circumstance may be accounted for by the accumulation at the base of the old shore lines of carbonate soil waters descending down the declivities, where they are subject to an increased evaporation.

6. The connection between the depth of the effervescing horizon with that of the permanent ice layer is exhibited in the effervescence commencing nearer to the surface when the permanent ice layer, and consequently the soil waters, are disposed at a greater depth; such has at least been observed to be the case in regard to more or less flat surfaces, all the other conditions being equal.

7. On steep declivities the relations indicated in paragraphs 5 and 6 are modified: under the influence of the percolation of the soil moisture the effervescence may

commence very close to the surface on declivities, although the permanent ice layer may be at a low depth from the surface; in such cases, however, [196] the contents of lime in the superior horizons of the soil is relatively small.

8. In the regions of the distribution of carbonatic loams the alluvial soils of perennial streams do not usually contain carbonates, while those of temporary water-courses (disappearing in summer) effervesce at a certain depth.

9. Soils of depressions, occurring chiefly in the proximity of lake banks, and having outlets in spring only, or none at all, are composed of carbonate alkalis, between which and the decomposed carbonatic soils of the interfluviatile tracts there seems to be a series of transitions. They are met with both in the south, and in the north.

10. The wide distribution over the flat elements of the relief under forest of carbonatic loams leached out from the surface especially towards the north, the soil sections exhibiting certain features characteristic of podzolization, affords grounds for assuming that the processes of degradation of these soils are relatively recent and the present epoch was preceded by one with a drier climate.

11. The recency of the process of leaching is indicated by the soils of the Lena arenaceous zone being deposited upon thin (often but 20-25 cm thick) superficial layers of loams and sandy loams underlaid by sand. In an overwhelming majority of cases, at least in the central and southern parts of the region, such soils effervesce at a certain depth, not infrequently beginning with the surface, notwithstanding the presence

of conditions very much favouring leaching. In the immediate proximity of the Aldan R. alone the argillaceous covering is under similar conditions entirely devoid of carbonates.

12. Occasionally, and chiefly in the Aldan region, the horizon B of the humous carbonatic soils has a reddish hue, which is typical of humous soils on loess.

13. The arenaceous soils of the north-western part of the Lena-Aldan plateau on flat patches of the relief and on declivities are devoid of carbonates elements and possess the character of typical 'podzol' soils.

14. The intensity of the process involved in podzolization on sands is dependent upon the relief and the depth of the permanent ice layer. The relation of this process to geographical posi-[197]tion has remained undetermined, its intensity on the north differring [sic] but slightly from that on the south.

15. The relations indicated above show that the strongly 'podzolized' soils with a thicker horizon A_2 (being the third sublayer of A counting from the surface) usually occur on softly sloping declivities and not on flat elements of the relief; on these latter the manifestation of the podzolizing process is relatively slight; at the same time a more intense process may be universally observed to ccour on areas, where the permanent ice layer is not far from the surface, in other words, where the level of the ground

waters is higher; finally, the thickness of the horizons A+B in many cases, is relatively very small (10-20 cm). The above indicates relatively unfavourable climatic conditions consisting above all in the amount of precipitation being inadequate towards the full development of the podzolizing process.

16. Both at the bottom, as well as on the inferior parts of the declivities of the closed depressions of the arenaceous region are widely spread highly alkaline soils (carbonate alkalis) effervescing at the very surface and sometimes containing grains of concretions of calcareous salts.

17. On the north, within the limits of forest growth in the region of the distribution of the terminal moraines of the Verkhoyansk glaciers and higher up the mountains, podzolized and marshy soils, usually very shallow and gravelly, are alone developed.

18. The character of these soils in the mountainous region depends upon the incidences of the relief and the degree of exposure of the declivity: on well drained elements of the relief exposed to the action of the sun's rays, the podzol soils, although not free from being slightly swamped, ascend to the very limits of tree growth; in the absence of such conditions, 'glei' bog soils or peat 'glei' bog (1) soils predominate, while in the shaded

1. Reduced clay and loam soils at a certain depth from the surface subject to constant moisture.

portions of steep valley declivities, along which the rain waters descend through coarse gravel, the soil is often totally wanting, being replaced by ice, deposited directly beneath a superficial growth of mosses and lichens. [198]

19. The genesis of the soils of the north western part of the Lena-Aldan plateau may be outlined as follows:

The disappearance of the Verkhoyansk glaciers and the initial stages of the gradual extinction of fossil firn ice in the region of the plateau were connected (1) with the

1. Brückner holds that in the Glacial age the summer in Siberia was 4-5° colder than it is at present, but the winter was correspondingly warmer. G. Brückner. Bemerkungen zu der Abhandlung des Herrn Lamansky über das Absterben der Gletscher. Zeitschrift für Gletscherkunde. Bd. VIII. H. 4. 1914. P. 195.

substitution of the relatively equable climate of the Glacial Period with its very cool summer by a climate still more continental than the present. Such a climate offered favourable conditions for the retention of salts in the soil and for the dispersion of herbaceous growth of a steppe type, both circumstances contributing to the development of dark coloured humous carbonatic soils, not infrequently approaching 'tchernoziom'

in certain features, which were deficient only on sands, and that not invariably. The climate subsequently evolved in the direction of an increase in summer precipitation and had a tendency towards softening the extremes of that season of the year. This modification of the climate was accompanied by the substitution of forest (taiga) for the steppe, which beneficial change could only be accomplished thanks to the larch, the least exacting of all Siberian trees. No other trees, with the exception of relatively small detached areas, meet as yet with suitable enough conditions for their growth. In the mountains only the birch may be pretty widely spread along with the larch, as is the pine on sands, where it even predominates. Such a conquest of the steppe by the forest naturally commenced in the mountain ranges surrounding the plateaus, where trees could take root so long ago as during the preeminently dry Post-Glacial period, subsequent changes in the climatic conditions first beginning to be felt at the base of the mountains. Under the influence of the gradual change in the climate and the altered vegetation the humous carbonatic soils became modified, and commencing with the superficial horizon began under the process of leaching to obtain certain features characteristic of podzol. Still, even in a relatively close proximity to the Verkhoyansk Range the changes in the climatic conditions were not powerful enough to radically affect the soils of completely or half closed depressions [199] highly charged with alkaline salts, which have apparently subsisted without considerable alterations. and into which, with the only exception of the region of non-carbonatic Lena sands, the forest has not

penetrated.

Such a sequence in the course of the changes to which the region was subject seems to account satisfactorily for the occurrence on the Aldan plateau of a series of steppe plant forms, as also of certain steppe animals, such as the 'ovrazhek' (suslik) met with by the author likewise in the Yana valley; these forms represent the surviving remnants of other conditions, which, as has been shown above, have not, however, changed so radically, as to have caused the complete extinction of the hardier aborigenes of the former steppes.

Here, as in other districts of Eurasia and in North America the general causes which had contributed to the softening of the extremes of the continental climate of the preceding epoch, could not have failed to act, the forest vegetation of the northern parts of Eurasia and in particular that of the countries bordering on the lower Yenisei, (1) having,

1. See Kuznetsov, N. J. Vegetation of the Yenisei tundra. Preliminary report of a botanical investigation of Siberia and Turkestan in 1914. Petrograd 1916, p. 28.

Grigoriev, A. A. The arctic boundaries of the forest growth in the Bolshezemelskaya and some other tundras. Zemlevedenie. Vol. XXVI, 1924, p. 86.

Lopatin. Journal of the Turukhansk expedition. 1866. Zap. Ross. Geogr. Obshch. po Obshch. Geogr. Vol. XXVIII, p.2, 1897, p.19.

under their influence, in comparison with the present epoch, extended not less than 150-200 klm further south. A certain importance, on the other hand, judging from the shape of the valleys, may be attributed to the probably recent sinking of the Verkhoyansk and Stanovoi Ranges, as also to the continuous subsidence of these mountains due to processes of denudation, in consequence of which the moist winds blowing in summer from the Ocean carried with them a somewhat greater quantity of precipitation than formerly."

ADDENDUM

to page 194.

After the major part of this work had passed through the press a series of new facts somewhat modifying the views stated therein have been disclosed during the author's second visit to Yakutia in the summer of 1926. Observations made then in the north-western part of the Vilui basin (on the river Tiung), as also on the shore terraces between Kachug and Yakutsk, much facilitated by the favourable weather conditions of that summer, lead to the inference that three ancient surfaces of denudation with residual eminences raised above the upper surface are present throughout the country. In instituting a comparison between these observations and those of W. J. Zverev relating to the middle course of the Aldan (1) (below the affluence of the Uchur) and to the

1. See W. Zverev. Brief report on geological investigations conducted in tre valley of the Aldan. Izv. Geol. Komit. 1913. Nr. 4.

Vilui above the mouth of the Akhtaranda, it appears that the entire Lena basin had been thrice subjected not only to periods of upheaval, but to a rigorous activity of running water. This circumstance stands in full agreement with the conclusions reached by

S.S. Neustruev (2) from observations made in the southern parts of Western Siberia

2. See S.S. Neustruev. Contributions to the study of Quaternary deposits in Siberia. Pochvovedenie, 1925, Nr. 3.

which the author mentioned connects, so far, it is true, but 'advisedly', with the three-fold glaciation of the Altai established by Granö. (3)

3. See Granö. On the Glacial Period in the Russian Altai. Izv. Zap. Sib. Otd. Russk. Geogr. Obshch. III. 1923 p. 11-21, and also his: Les formes du relief dans l'Altai russe et leur génèse. Fennia, m.40. 1919.

The above affords sufficient grounds for admitting that the Verkhoyansk Mountain Chain in the Postpliocene age was subject not only to three upheavals, as has been shown by the author in this work, but to three periods of glaciation (instead of two). The first period embraced the Tertiary peneplain, the [201] second was connected with the elevated surface of erosion cut into this plain, and the third with the lower glacial terrace. Therefore, everything which is attributed in this volume to the agency of the ice of the first period of glaciation should be assigned to that of the second period, and

what is connected with the glaciers of the second period should be relegated to those of the second. The first period of glaciation apparently yielded in intensity to the second, in consequence of which the relief has lost many forms connected with that age and among them independent systems of terminal moraines."